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Indoor Gamma Ray Measurements, Activity Concentrations And Radiation Hazard Assessment Of Residential Mud Buildings In Miango, North Central Nigeria.

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Abstract

Natural radioactivity levels and radiation risks from mud buildings in Miango, North Central Nigeria have been assessed. The town is located within Naraguta Sheet 168 NW. The area is underlain mainly by porphyritic Pan-African granites, Mesozoic anarogenic Younger Granite consisting of biotite granite and granite porphyry, and newer basalt. Weathering and decomposition of these rocks have produced thick layers of clayey soils (mud) which are used for building residential houses. Concentrations of ^{238}U, ^{232}Th and ^{40}K in the mud houses were determined using RS-230 Gamma Spectrometer integrated with a BGO (Bismuth Germanate Oxide) detector for improved accuracy. The content of ^{238}U, ^{232}Th and ^{40}K in the mud houses varies from 3.77-10.77ppm, 27.08-73.77ppm, and 1.47–6.27% respectively. Activity concentrations of these radioelements vary from 46.52-132.97 Bq/Kg for ^{238}U, 109.76-299.49 Bq/Kg for ^{232}Th, and 459.07-1961.47 Bq/Kg for ^{40}K. On the basis of these activity concentrations, radiation exposure parameters such as absorbed dose rate in air, annual effective dose equivalent, radium equivalent activity, excess lifetime cancer risk, and internal hazard index were calculated for the buildings. Results obtained vary from 146.79-291.69 nGy/h, 0.68-1.34 mSv/yr, 322.49-642.26 Bk/kg, 2.36 $x10^{-3}$- 4.70 $x10^{-3}$, and 1.00-2.08 respectively. These values are generally high for safety, thus suggesting that there is a good chance that using the clayey soils from this area for building houses may have negative health implications on the inhabitants in the long term.

Keywords: Uranium. Thorium. Potassium. Activity concentration. Absorbed dose rate in air. Annual effective dose equivalent. Radium equivalent activity. Excess lifetime cancer risk. Internal hazard index. Miango.

1. Introduction

Ionizing radiation refers to any type of particle or electromagnetic wave that carries enough energy to ionize or remove electrons from an atom. It is capable of disrupting life processes. Ionizing radiation comes from soils and rocks (primordial), cosmic ray interactions (cosmogenic), and from man-made radionuclides. Terrestrial radiation (primordial) is from naturally occurring radionuclides (NORMS) present in various concentrations in the environment. Radiation is found in soils as a result of the presence of the natural radionuclides in them, the most significant of which are ^{238}U, ^{232}Th and ^{40}K. Exposure to terrestrial radiation can be internal and external. While internal exposure comes through ingestion (food and water pathways) and inhalation, external exposure comes as a result of indoor or outdoor gamma radiation interacting directly with the skin.

Most materials used for building construction are derived from rock and soil which contain different amounts of ^{238}U, ^{232}Th and ^{40}K, thereby making them radioactive. Indoor exposures to gamma radiation depend on the time spent indoor per day, as well as the construction materials used. Rock materials cut as dimension colomns, cladding pads, stone aggregates, laterites, sands and soils, present higher indoor radiation compared to wooden materials. Some construction materials can cause substantial radiation exposure if they contain elevated levels of naturally occurring radionuclides (Bendibbie *et al*., 2013).

Miango area, north central Nigeria is situated on an elevation of about 1300 metres above mean sea level. It experiences regular rainfall while thick reddish lateritic soils which are products of *in-situ* weathering of rocks abound in the area. The clayey soils (mud) are usually mixed with water, molded into bricks or rounded masses and sandwiched with dry savannah grasses when used for building houses. This is a common practice in semi

urban communities in Northern Nigeria. This work is aimed at determining the radiation exposure levels in these buildings because of health concern.

2. Geology of Miango Area

Miango area is underlain by porphyritic Pan-African granite belonging to the Basement Complex of Nigeria, Mezozoic anarogenic biotite granite and granite porphyry which are constituent part of the Miango Complex (Bowden et al 1976, Buchanan et al 1971, Kinnaird et al 1981), as well as newer basalt of Quaternary age (Figure 1). The Miango Complex is a simple intrusion and constitutes a small portion of this area, located west of Jos-Bukuru Complex. The form of intrusion within the Miango Complex is emplacement by cauldron subsidence.

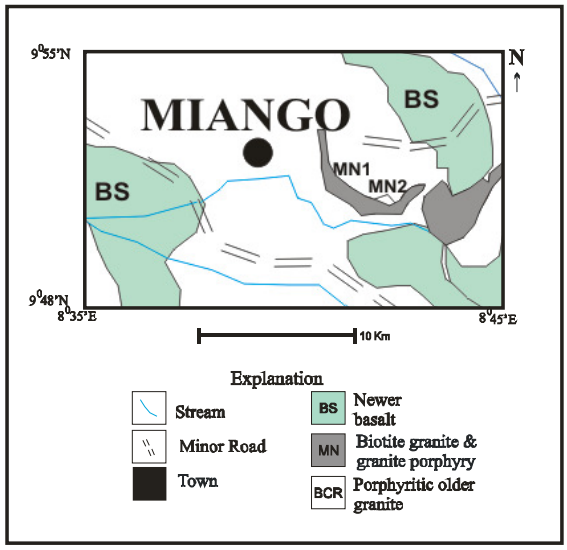

Figure 1. Simplified geological map of Miango area.

3. Materials and Method

Measurements of Gamma radiation were carried out inside forty eight (48) selected buildings using RS-230 Gamma Spectrometer (Figure 2). It is a handheld auto-stabilized 1024 channel spectrometer which uses a large (103 cm^3) BGO (Bismuth Germanate Oxide) detector for improved level of system sensitivity and accuracy. The use of a BGO gives very significant increase in performance over the normal NaI detector. A preset time of 120 seconds was used for the measurement per point to allow for better accuracy, while the assay mode provided the concentrations of Potassium (K %), equivalent Thorium (eTh) in ppm, and equivalent Uranium (eU) in ppm for each point of measurement. The energy response of the equipment is 30–3000kev. Several measurements were taken within each building and the average value for each calculated. These values were then converted into activity concentrations in Bq/kg. With these activity concentration values, the levels of exposures by the inhabitants to radiation hazards such as absorbed dose rate in air, annual effective dose equivalent, radium equivalent activity, excess lifetime cancer risk, and internal hazard index were then computed.

Figure 2. RS-230 BGO Handheld Gamma-Ray Spectrometer.

3.1 Absorbed Dose Rate in Air.

The indoor absorbed dose rate in the air due to gamma rays 1 metre above the ground was calculated according to UNSCEAR (2000), using Equation 1.

$$D\ (nGy/h) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \qquad (1)$$

Where 0.462, 0.621 and 0.0417 are the conversion factors for ^{238}U, ^{232}Th and ^{40}K respectively. It was assumed that the contributions from other natural radionuclides are negligible.

3.2 Annual Effective Dose Equivalent (AEDE).

Annual effective dose equivalents were calculated for both indoor and outdoor. The annual effective dose equivalents for indoor environment were calculated using Equation 2, and for outdoor using Equation 3.

$$AEDE_{Indoor}\ (mSvy^{-1}) = D\ (nGyh^{-1})\ x\ 8760\ hy^{-1}\ x\ 0.75\ x\ 0.7SvGy^{-1}x\ 10^{-6} \quad (2)$$

$$AEDE_{Outdoor}\ (mSvy^{-1}) = D\ (nGyh^{-1})\ x\ 8760\ hy^{-1}\ x\ 0.25\ x\ 0.7SvGy^{-1}\ x\ 10^{-6} \quad (3)$$

Where D is the absorbed dose in air, 8760 (*24x365)* is the number of hours in a year, 0.75 and 0.25 are the indoor and outdoor occupancy factor respectively, which represents the fraction of time spent indoor and outdoor, and $0.7SvGy^{-1}$ is the conversion coefficient from absorbed dose in air to effective dose received by adults. UNSCEAR (1993) recommended 0.8 and 0.2 as the indoor and outdoor occupancy factors respectively. However, from interactions and interview with people in this community, it was established that an average of about 6 hours are spend outdoor daily for farming and/or for other activities, while the remaining 18 hours of the day are spent indoor. This implies that the occupancy factor is about 0.75 indoor and 0.25 for outdoor.

3.3 Radium Equivalent Activity (Ra_{eq})

Radium equivalent activity is an index for assessment of radiological hazards associated with ^{238}U, ^{232}Th and ^{40}K in building materials. Radium equivalent activity of each building was calculated according to Beretka & Matthew (1985) as follows:

$$Ra_{eq}\ (Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \qquad (4)$$

Where A_{Ra}, A_{Th} and A_K are the specific activity concentrations of uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) respectively.

The equation is based on the estimation that 370 Bq/kg of ^{238}U, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same gamma ray dosage. The maximum value of Ra_{eq} is set at 370 Bq/kg for safety. This value is equivalent to a maximum permissible dose of 1.5mSv/y to human from exposures to natural radiation.

3.4 Excess Lifetime Cancer Risk (ELCR)

Cancer risk is the likelihood, or chance, of getting cancer. Excess lifetime cancer risk estimates the additional probability of cancer incidence in a population for a specific lifetime from projected intakes (and exposures) and chemical-specific dose-response data. In line with the position of Ramasamy et al., (2009), Emelue et al., (2014), the excess lifetime cancer risk (ELCR) was calculated using Equation 5.

$$ELCR = AEDE \times DL \times RF \qquad (5)$$

Where AEDE is the annual effective dose equivalent, DL is the average duration of life (70 years), and RF is the risk factor or fatal cancer risk per Sievert. ICRP (1991) peg RF at 0.05 for the public.

3.5 Internal Hazard Index

The Internal hazard index is a reflection of the internal exposure to radiation. It was calculated using Equation 6 according to Shoeib and Thabayneh (2014).

$$H_{in} = A_U/185 + A_{Th}/259 + A_K/4810 \qquad (6)$$

Where A_U, A_{Th} and A_K are the specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K respectively.

The internal hazard index should be less than 1 to provide a level of safety for the individuals living in the dwellings.

4. Results and Discussion

Concentrations of ^{238}U, ^{232}Th and ^{40}K in the mud houses (Table 1) vary from 3.77-10.77 ppm, 27.08-73.77 ppm, and 1.47–6.27% respectively. The average values are 7.90 ppm for ^{238}U, 44.82 ppm for ^{232}Th, and 3.09 % for ^{40}K. These values are higher than the average crustal abundance of these radionuclides which are reported at 2-3 ppm, 8-12 ppm, and 2-2.5% respectively (International Atomic Energy Agency IAEA (2003). According to Faure 1986 and Mènager et al. 1993, granitic rocks are generally known to be enriched in Th and U (on an average 15 µg/g of Th and 5 µg/g of U), compared to rocks of basaltic or ultramafic composition (< 1 µg/g of U). Potassium is also a major constituent in many igneous rocks. Igneous rocks of granitic composition are therefore associated with higher levels of radiation.

Activity concentrations were obtained by multiplying the concentrations of the radionuclides within each building (Table 1) by the conversion factors for the radionuclides (Table 2). Results obtained vary from 46.52-132.97 Bq/Kg for ^{238}U, 109.76-299.49 Bq/Kg for ^{232}Th, and 459.07-1961.47 Bq/Kg for ^{40}K (Table 3). These values are above the range of activity concentrations in many countries as shown in Table 4. The average values obtained from this study are 88.23 Bq/Kg, 181.97 Bq/Kg and 967.41 Bq/Kg respectively. These average values are also above the world average of 33 for ^{238}U, 45 for ^{232}Th, and 420 Bq/Kg for ^{40}K (UNSCEAR 2000).

The indoor absorbed dose rate in the air due to gamma rays obtained in this study (Table 5) varies from 146.79 -

291.69 nGy/h, with an average of 193.74 nGy/h. This is higher than the average values for many countries as shown in Table 6. The annual effective dose equivalents for indoor environment in the area (Table 5) ranges from 0.68-1.34 mSv/yr with an average of 0.92 mSv/yr while that of outdoor is 0.23-0.45 mSv/yr, with an average of 0.31mSv/yr. These average values are more than the global average of 0.41 mSv/yr for indoor and 0.06 mSv/yr for outdoor (UNSCEAR 2000).

Table 1. Concentrations of ^{238}U, ^{232}Th and ^{40}K in the mud houses investigated in Miango, North Central Nigeria.

SNo	Building ID	U (ppm)	Th (ppm)	K %	SNo	Building ID	U (ppm)	Th (ppm)	K %
1	MB1	4.07	30.63	4.13	25	MB25	8.83	58.23	2.93
2	MB2	4.77	27.03	4.50	26	MB26	9.50	61.20	3.03
3	MB3	6.17	51.60	5.10	27	MB27	10.77	65.50	3.40
4	MB4	5.43	54.33	4.83	28	MB28	8.10	62.67	3.23
5	MB5	6.00	45.63	4.20	29	MB29	9.87	54.17	2.97
6	MB6	7.17	59.57	5.00	30	MB30	10.07	56.30	2.97
7	MB7	7.93	57.50	6.27	31	MB31	8.40	66.20	2.67
8	MB8	4.87	48.67	5.60	32	MB32	9.20	49.97	3.13
9	MB9	4.53	30.30	4.90	33	MB33	8.07	46.90	2.47
10	MB10	3.87	29.33	4.33	34	MB34	7.30	48.70	2.90
11	MB11	5.50	32.80	4.97	35	MB35	7.20	46.73	3.10
12	MB12	3.77	31.47	4.80	36	MB36	9.37	43.70	2.17
13	MB13	6.70	35.17	2.87	37	MB37	9.30	43.20	2.37
14	MB14	6.93	34.77	1.50	38	MB38	8.53	44.70	3.17
15	MB15	7.70	37.10	1.47	39	MB39	7.27	37.10	2.37
16	MB16	8.13	37.00	1.70	40	MB40	6.87	38.70	2.87
17	MB17	5.57	44.20	1.93	41	MB41	5.83	36.70	4.07
18	MB18	6.97	49.40	2.43	42	MB42	6.50	33.97	2.83
19	MB19	7.83	54.23	3.33	43	MB43	5.97	32.63	3.13
20	MB20	5.87	53.37	3.00	44	MB44	6.00	33.20	2.87
21	MB21	6.47	49.40	2.70	45	MB45	6.70	39.80	4.23
22	MB22	5.70	52.40	2.00	46	MB46	6.00	38.77	3.73
23	MB23	8.27	50.77	2.83	47	MB47	6.00	38.93	3.90
24	MB24	10.37	73.77	3.57	48	MB48	7.90	46.97	3.97
					MIN		3.77	27.03	1.47
					MAX		10.77	73.77	6.27
					AVERAGE		7.90	44.82	3.09
					MEDIAN		7.08	45.22	2.98
					ST.DEVIA.		1.88	11.78	0.95

Table 2. Conversion factors from equivalent concentration (ppm, %) to activity in Bq/kg (IAEA 1989).

1% K	313 Bq/kg	^{40}K
eU (ppm)	12.35 Bq/kg	^{238}U or ^{226}Ra
eTh (1ppm)	4.06 Bq/kg	^{232} Th

Table 3. Activity concentrations of ^{238}U, ^{232}Th and ^{40}K within the mud houses in Miango, North Central Nigeria.

SNo	Building ID	U (Bq/kg)	Th (Bq/kg)	K (Bq/kg)	SNo	Building ID	U (Bq/kg)	Th (Bq/kg)	K (Bq/kg)
1	MB1	50.22	124.37	1293.73	25	MB25	109.09	236.43	918.13
2	MB2	58.87	109.76	1408.50	26	MB26	117.33	248.47	949.43
3	MB3	76.16	209.50	1596.30	27	MB27	132.97	265.93	1064.20
4	MB4	67.10	220.59	1512.83	28	MB28	100.04	254.43	1012.03
5	MB5	74.10	185.27	1314.60	29	MB29	121.85	219.92	928.57
6	MB6	88.51	241.84	1565.00	30	MB30	124.32	228.58	928.57
7	MB7	97.98	233.45	1961.47	31	MB31	103.74	268.77	834.67
8	MB8	60.10	197.59	1752.80	32	MB32	113.62	202.86	980.73
9	MB9	55.99	123.02	1533.70	33	MB33	99.62	190.41	772.07
10	MB10	47.75	119.09	1356.33	34	MB34	90.16	197.72	907.70
11	MB11	67.93	133.17	1554.57	35	MB35	88.92	189.74	970.30
12	MB12	46.52	127.75	1502.40	36	MB36	115.68	177.42	678.17
13	MB13	82.75	142.78	897.27	37	MB37	114.86	175.39	740.77
14	MB14	85.63	141.15	469.50	38	MB38	105.39	181.48	991.17
15	MB15	95.10	150.63	459.07	39	MB39	89.74	150.63	740.77
16	MB16	100.45	150.22	532.10	40	MB40	84.80	157.12	897.27
17	MB17	68.75	179.45	605.13	41	MB41	72.04	149.00	1272.87
18	MB18	86.04	200.56	761.63	42	MB42	80.28	137.90	886.83
19	MB19	96.74	220.19	1043.33	43	MB43	73.69	132.49	980.73
20	MB20	72.45	216.67	939.00	44	MB44	74.10	134.79	897.27
21	MB21	79.86	200.56	845.10	45	MB45	82.75	161.59	1325.03
22	MB22	70.40	212.74	626.00	46	MB46	74.10	157.39	1168.53
23	MB23	102.09	206.11	886.83	47	MB47	74.10	158.07	1220.70
24	MB24	128.03	299.49	1116.37	48	MB48	97.57	190.68	1241.57
						MIN	46.52	109.76	459.07
						MAX	132.97	299.49	1961.47
						AVERAGE	88.23	181.97	967.41
						MEDIAN	86.77	183.59	933.78
						ST.DEVIA.	23.17	47.82	298.90

Table 4. Range of activity concentrations in some countries compared with values from the study area

SNo	Country	^{238}U Bq/Kg	^{232}Th Bq/Kg	^{40}K Bq/Kg	Source
1	Ireland	8-120	3-60	40-80	McAulay & Moran 1988).
2	Netherland	5-53	8-77	120-730	Köster et al 1988
3	United States	4-140	4-130	100-700	Myrick et al 1983
4	China	2-690	1-360	9-1800	Zhi 1992
5	Hongkong	25-130	16-200	80-1100	Wong et al 1999
6	United Kingdom	2-330	1-180	0-3200	Bradley 1993
7	Poland	5-120	4-77	110-970	Jagielak et al 1992
8	Romania	8-60	11-75	250-1100	Iacob 1996
The study area (Miango)		46.52-132.97	109.76-299.49	459.07-1961.47	
Average for study area		88.23	181.97	967.41	
World Average		33	45	420	UNSCEAR 2000

Radium equivalent activity calculated for the buildings (Table 5) range from 322.49-642.26 Bq/kg with an average value of 434.60 Bq/Kg. Here, 73% of the buildings showed values in excess of 370Bq/Kg maximum allowable limit thus suggesting that radiation safety may be a major concern in such buildings.

Excess lifetime cancer risk (ELCR) obtained for indoors in this study (Table 5) range from 2.36 $x10^{-3}$- 4.70 $x10^{-3}$, with an average of 3.22 $x10^{-3}$, and from 0.79 $x10^{3}$-1.57 $x10^{-3}$ with an average of 1.07 $x10^{-3}$ for outdoor. The average total excess lifetime cancer risk (indoor and outdoor) is 2.145 $x10^{-3}$. This is higher than the world's average of 1.45×10^{-3}. There is always a chance that a person will get some type of cancer at some stage in life. Excess lifetime cancer risk is the additional risk that someone might get cancer if that person is exposed to cancer-causing materials for a long time.

Internal hazard index calculated for the buildings (Table 5) vary from 1.00-2.08 with an average of 1.41.For the radiation hazard to be insignificant; the value of the hazard index must be less than unity. There is therefore a safety concern here as values obtained are more than 1.

Table 5. Radiation parameters for mud houses in Miango, North Central Nigeria.

SNo	ID	D (nGy/h)	AEDE Indoor (mSv/yr)	AEDE Outdoor (mSv/yr)	Ra Eq. (Bq/kg)	ELCR $x10^{-3}$ (Indoor)	ELCR$x10^{-3}$ (Outdoor)	Hazard Index (Internal)
1	MB1	154.39	0.71	0.24	327.69	2.49	0.83	1.02
2	MB2	154.09	0.71	0.24	324.28	2.48	0.83	1.03
3	MB3	231.85	1.07	0.36	498.66	3.73	1.24	1.55
4	MB4	231.07	1.06	0.35	499.03	3.72	1.24	1.53
5	MB5	204.11	0.94	0.31	440.26	3.29	1.10	1.39
6	MB6	256.33	1.18	0.39	554.85	4.13	1.38	1.74
7	MB7	272.03	1.25	0.42	582.85	4.38	1.46	1.84
8	MB8	223.56	1.03	0.34	477.62	3.60	1.20	1.45
9	MB9	166.22	0.76	0.25	350.00	2.68	0.89	1.10
10	MB10	152.58	0.70	0.23	322.49	2.46	0.82	1.00
11	MB11	178.90	0.82	0.27	378.06	2.88	0.96	1.20
12	MB12	163.48	0.75	0.25	344.89	2.63	0.88	1.06
13	MB13	164.31	0.76	0.25	356.02	2.64	0.88	1.19
14	MB14	146.79	0.68	0.23	323.63	2.36	0.79	1.11
15	MB15	156.62	0.72	0.24	345.85	2.52	0.84	1.19
16	MB16	161.88	0.74	0.25	356.24	2.61	0.87	1.23
17	MB17	168.44	0.77	0.26	371.96	2.71	0.90	1.19
18	MB18	196.06	0.90	0.30	431.49	3.16	1.05	1.40
19	MB19	224.94	1.03	0.34	491.95	3.62	1.21	1.59
20	MB20	207.18	0.95	0.32	454.59	3.33	1.11	1.42
21	MB21	196.69	0.90	0.30	431.73	3.17	1.06	1.38
22	MB22	190.74	0.88	0.29	422.82	3.07	1.02	1.33
23	MB23	212.14	0.98	0.33	465.11	3.41	1.14	1.53
24	MB24	291.69	1.34	0.45	642.26	4.70	1.57	2.08
25	MB25	235.51	1.08	0.36	517.88	3.79	1.26	1.69
26	MB26	248.10	1.14	0.38	545.75	3.99	1.33	1.79
27	MB27	270.95	1.25	0.42	595.19	4.36	1.45	1.97
28	MB28	246.42	1.13	0.38	541.80	3.97	1.32	1.73
29	MB29	231.59	1.07	0.36	507.84	3.73	1.24	1.70
30	MB30	238.11	1.10	0.37	522.69	3.83	1.28	1.75

Table 5 (Continued)

SNo	ID	D (nGy/h)	AEDE Indoor (mSv/yr)	AEDE Outdoor (mSv/yr)	Ra Eq. (Bq/kg)	ELCR x10^{-3} (Indoor)	ELCRx10^{-3} (Outdoor)	Hazard Index (Internal)
31	MB31	249.64	1.15	0.38	552.35	4.02	1.34	1.77
32	MB32	219.37	1.01	0.34	479.23	3.53	1.18	1.60
33	MB33	196.47	0.90	0.30	431.36	3.16	1.05	1.43
34	MB34	202.29	0.93	0.31	442.79	3.26	1.09	1.44
35	MB35	199.37	0.92	0.31	434.96	3.21	1.07	1.41
36	MB36	191.90	0.88	0.29	421.61	3.09	1.03	1.45
37	MB37	192.87	0.89	0.30	422.71	3.10	1.03	1.45
38	MB38	202.72	0.93	0.31	441.23	3.26	1.09	1.48
39	MB39	165.89	0.76	0.25	362.18	2.67	0.89	1.22
40	MB40	174.17	0.80	0.27	378.57	2.80	0.93	1.25
41	MB41	178.89	0.82	0.27	383.12	2.88	0.96	1.23
42	MB42	159.71	0.73	0.24	345.76	2.57	0.86	1.15
43	MB43	157.22	0.72	0.24	338.67	2.53	0.84	1.11
44	MB44	155.36	0.71	0.24	335.94	2.50	0.83	1.11
45	MB45	193.83	0.89	0.30	415.85	3.12	1.04	1.35
46	MB46	180.70	0.83	0.28	389.14	2.91	0.97	1.25
47	MB47	183.30	0.84	0.28	394.13	2.95	0.98	1.26
48	MB48	215.26	0.99	0.33	465.84	3.46	1.15	1.52
MINIMUM		146.79	0.68	0.23	322.49	2.36	0.79	1.00
MAXIMUM		291.69	1.34	0.45	642.26	4.70	1.57	2.08
AVERAGE		193.74	0.92	0.31	434.60	3.22	1.07	1.41
MEDIAN		194.94	0.90	0.30	431.42	3.16	1.05	1.41
ST.DEVIA.		41.30	0.17	0.06	81.78	0.59	0.20	0.26

Table 6. Range of absorbed dose rate in the air in some countries compared with values for the study area.

S/No	Country	D (nGy/h)	Source
1	United States	38	Oakley 1972
2	Chile	61	Stuardo 1996
3	China	99	NEPA 1990
4	Hongkong	200	Wong et al 1999
5	Japan	53	Abe et al 1980
6	Denmark	54	Nielsen 1977
7	Norway	79	Stranden 1977
8	Sweden	110	Mjönes 1986
9	France	75	Rannou et al 1985
10	United Kingdom	60	Wrixon 1988
Average for study area (Miango)		193.74	

5. Conclusion

Using the RS-230 Gamma Spectrometer, the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in mud building within Miango in North Central Nigeria have been studied and radiation hazard parameters which include absorbed dose rate in air, annual effective dose equivalent, radium equivalent activity, excess lifetime cancer risk, and internal hazard index calculated. The results obtained for these radiation parameters are higher compared with results from similar studies carried out in some other parts of the world. While ^{238}U and ^{232}Th concentrations are within the ranges found in most countries, ^{40}K is generally high in the rocks here. Both the porphyritic older granite and the biotite granites found here have high ^{40}K content. The values of radiation parameters found here tend to suggest that the inhabitants of those buildings may develop radiation related health problems in the long term.

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